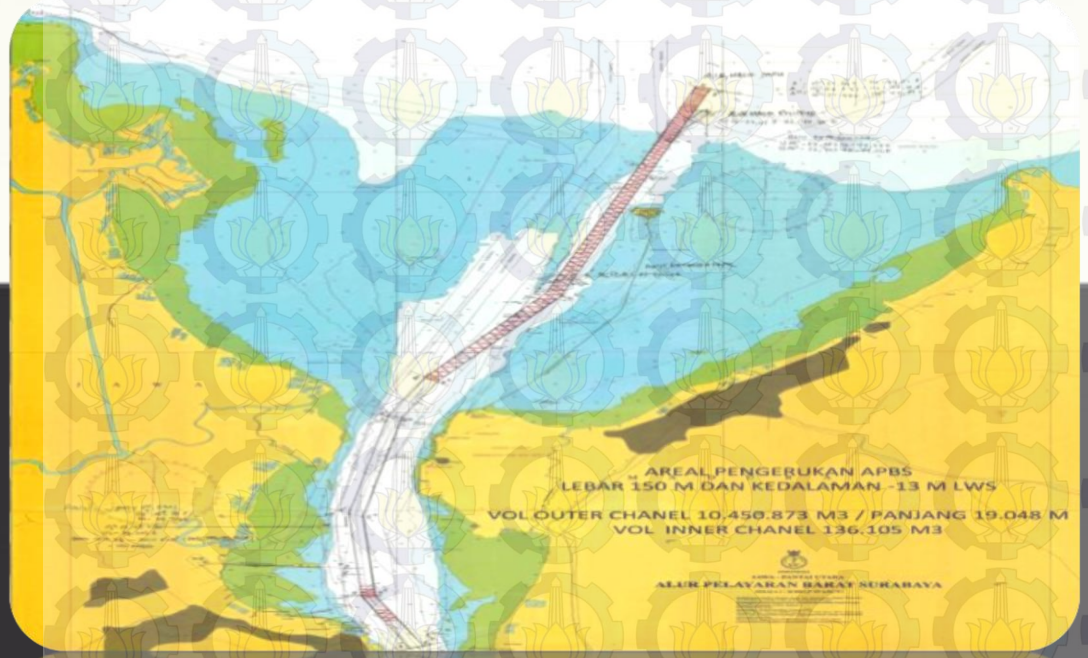
# Tesis

# ESTIMASI PELUANG TUBRUKAN KAPAL DENGAN METODE *MINIMUM DISTANCE TO COLLISION* (MDTC), STUDI KASUS : ALUR PELAYARAN BARAT SURABAYA



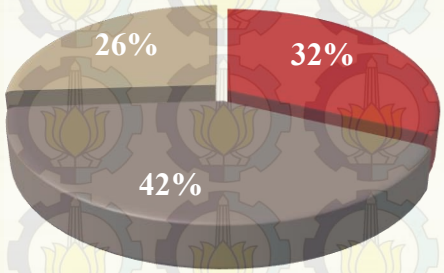

**Oleh :**
**Benedicta Dian Alfanda**
**4113204007**

# Daftar Isi

1. Pendahuluan
2. Perumusan Masalah, Batasan Masalah, Tujuan
3. Dasar Teori
4. Flowchart Pengerjaan Tesis
5. Perhitungan Peluang Tubrukan Kapal :
   - A. Traffic Based Models
   - B. Minimum Distance To Collision
6. Plotting Area pada QGIS
7. Kesimpulan dan Saran

# 1. PENDAHULUAN

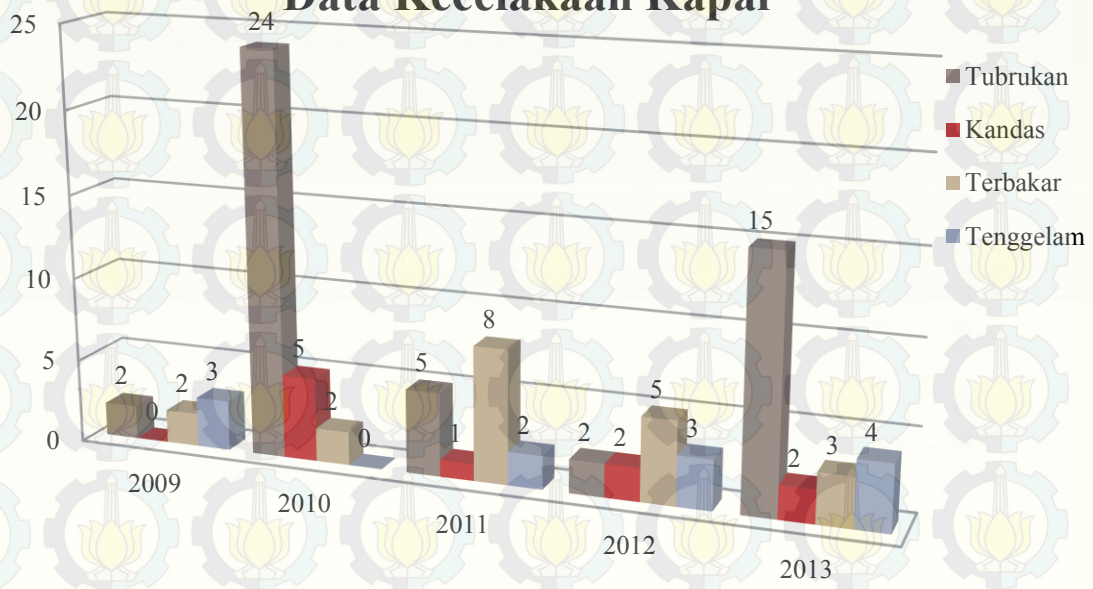
## Persentase Kecelakaan Kapal Laut 2012




(Sumber : Database KNKT)

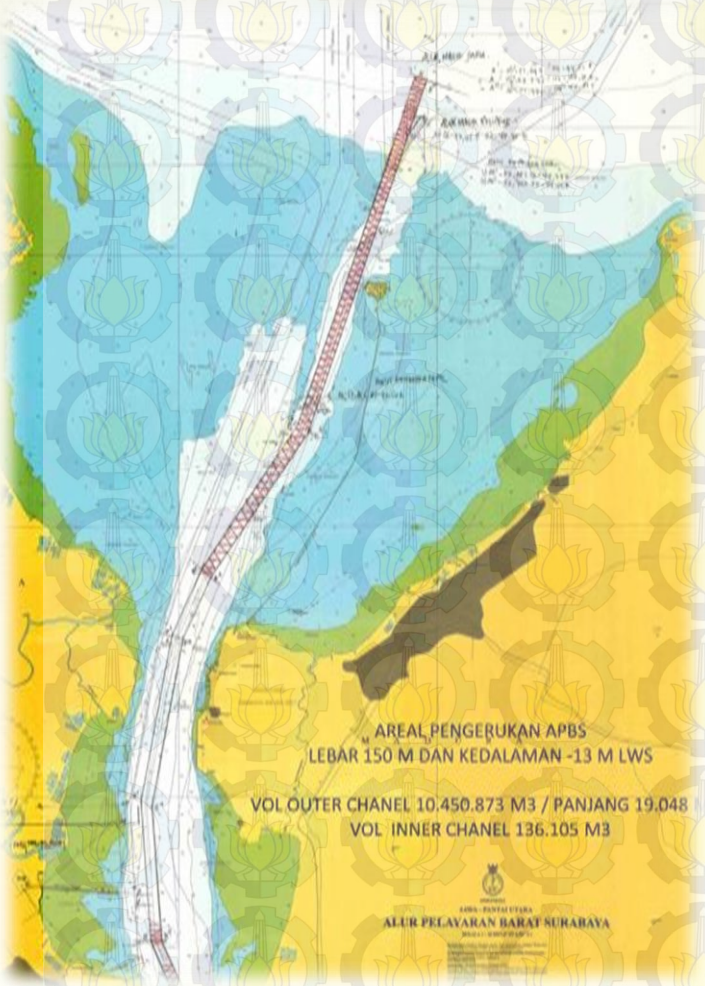
Dokumentasi Investigasi KNKT

## Data Kecelakaan Kapal




(Sumber : Database Syahbandar Kelas Utama Tanjung Perak Surabaya

# Rencana Revitalisasi Alur Pelayaran Barat Surabaya




Sumber : Peta Dishidros TNI AL No. 96a

| No. | Deskripsi | Alur Eksisting | Setelah Revitalisasi |
|---|---|---|---|
| 1. | Kondisi Fisik<br>-Panjang<br>-Lebar<br>-Kedalaman | <br>25 Nautical Mile<br>100 meter<br>-9.5 LWS | <br>25 Nautical Mile<br>200 meter<br>-12 LWS (Tahap Awal) |
| 2. | Volume Pengerukan | 700.000 $m^3$/3 tahun | 2,3 juta m $^3$setiap tahun |
| 3. | **Kecelakaan Pelayaran** | **Sering Terjadi** | **Dapat Diminimalkan** |
| 4. | Pelayanan | Satu Arah | Dua Arah |
| 5. | Model Pengelolaan | Oleh Pemerintah<br>Tanpa Channel Fee | Oleh Swasta<br>Dengan Channel Fee |
| 6. | Biaya Perawatan | Beban Pemerintah | Bukan Beban Pemerintah |
| 7. | Kapasitas Traffic | 27.000 Gerakan Kapal/Tahun | 59.000 Gerakan Kapal/Tahun |

## Proses Pengerukan APBS

Sumber : Majalah Dermaga

# 2. Perumusan Masalah, Batasan Masalah dan Tujuan

## Perumusan Masalah

- Bagaimana melakukan perhitungan peluang tubrukan kapal dengan menggunakan metode *Traffic Based Models*
- Bagaimana melakukan perhitungan peluang tubrukan kapal dengan menggunakan metode *Minimum Distance to Collision*
- Bagaimana menentukan nilai Pc *(Causation Probability)* di Alur Pelayaran Barat Surabaya.
- Bagaimana pemetaan lokasi bahaya berdasarkan frekuensi tubrukan kapal di Alur Pelayaran Barat Surabaya?

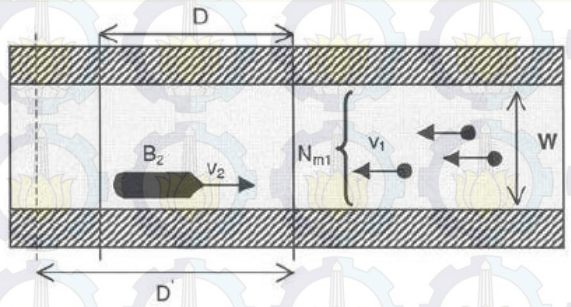
## Batasan Masalah

- Obyek penelitian adalah Alur Pelayaran Barat Surabaya (Selat Madura).
- Skenario tubrukan kapal: *head-on, overtaking* dan *crossing*.
- Analisa peluang tubrukan *Minimum Distance to Collision (MDTC)* akan dibandingkan dengan *Traffic Based Model.*

## Tujuan

- untuk mengetahui peluang tubrukan kapal dengan metode *Minimum Distance to Collision (MDTC)* dibandingkan dengan *Traffic Based Model* di perairan selat Madura serta memberikan alternatif solusi atau rekomendasi jika peluang tubrukan kapal berada pada level yang tidak dapat diterima (≥ 1 kejadian).

# Traffic Based Models-Head On




$$*\rho = \frac{Nm}{V_1 * W}$$

$$*N_i = \frac{(B_1+B_2)}{W} * \frac{(V_1+V_2)}{V_1 * V_2} * D * N_m$$

$$*Pa = Ni * Pc$$

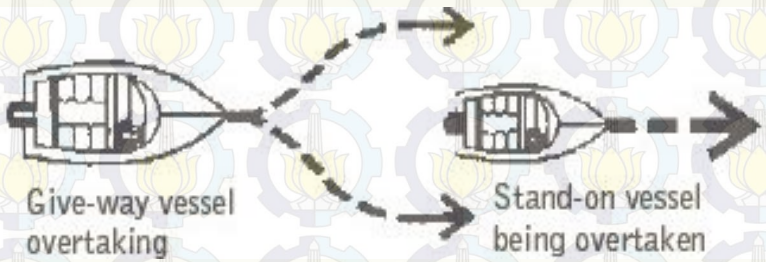
$$*Na = Pa * Nm$$

Daftar Simbol :

| | |
|---|---|
| $\rho$ | : kepadatan lalu lintas kapal (kapal/nm$^2$) |
| $Nm$ | : jumlah kapal yang melintas (kapal/satuan waktu) |
| $V_1$ | : rata-rata kecepatan kapal yang ditemui |
| $V_2$ | : kecepatan kapal subyek |
| $W$ | : lebar alur pelayaran (m) |
| $Ni$ | : perkiraan jumlah tubrukan per lintasan di sebuah jalur pelayaran |
| $D$ | : panjang lintasan |
| $Pa$ | : *probability accident* |
| $B_1$ | : rata-rata lebar kapal yang melintas (m) |
| $B_2$ | : lebar kapal subyek (m) |
| $Pc$ | : faktor penyebab kecelakaan |

(Sumber : Kristiansen, 2005)

# Traffic Based Models-Overtaking




$$*\rho = \frac{Nm}{V_1 * W}$$

$$*N_i = \frac{(B_1+B_2)}{W} * \frac{(V_1-V_2)}{V_1 * V_2} * D * N_m$$

$$*Pa = Ni * Pc$$

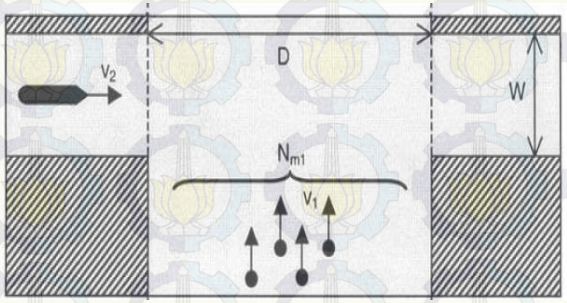
$$*Na = Pa * Nm$$

Daftar Simbol :

| | |
|---|---|
| $\rho$ | : kepadatan lalu lintas kapal (kapal/nm$^2$) |
| $Nm$ | : jumlah kapal yang melintas(kapal/satuan waktu) |
| $V_1$ | : rata-rata kecepatan kapal yang ditemui |
| $V_2$ | : kecepatan kapal subyek |
| $W$ | : lebar alur pelayaran (m) |
| $Ni$ | : perkiraan jumlah tubrukan per lintasan di sebuah jalur pelayaran |
| $D$ | : panjang lintasan |
| $Pa$ | : *accident probability* |
| $B_1$ | : rata-rata lebar kapal yang melintas (m) |
| $B_2$ | : lebar kapal subyek (m) |
| $Pc$ | : faktor penyebab kecelakaan |

(Sumber : Kristiansen, 2005)

# Traffic Based Models-Crossing




$$*\rho = \frac{Nm}{V_1 * W}$$

$$*P_i = \frac{Nm}{V_1 * V_2} * [(B_1 + L_2) * V_1 + (L_1 + B_2) * V_2]$$

$$*Pa = Pi * \boldsymbol{Pc}$$

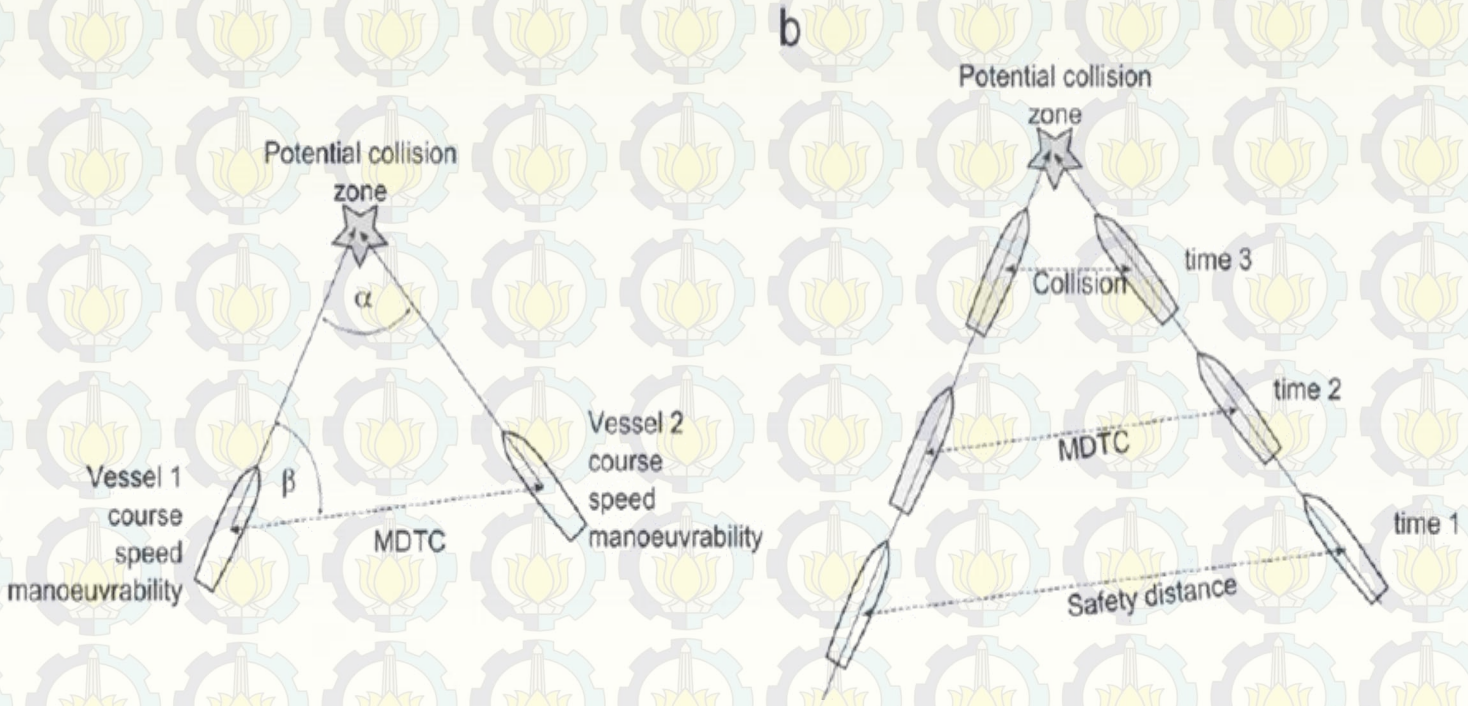
$$*Na = Pa * Nm$$

Daftar Simbol :

| | |
|---|---|
| $\rho$ | : kepadatan lalu lintas kapal (kapal/nm2) |
| $Nm$ | : jumlah kapal yang melintas(kapal/satuan waktu) |
| $V_1$ | : rata-rata kecepatan kapal yang ditemui |
| $V_2$ | : kecepatan kapal subyek |
| $W$ | : rata-rata lebar alur pelayaran (m) |
| $Pi$ | : *impact probability* |
| $Pa$ | : *accident probability* |
| $L_1$ | : Rata-rata panjang kapal yang melintas (m) |
| $L_2$ | : Panjang kapal subyek (m) |
| $B_1$ | : rata-rata lebar kapal yang melintas (m) |
| $B_2$ | : lebar kapal subyek (m) |
| $Pc$ | : faktor penyebab kecelakaan |

(Sumber : Kristiansen, 2005)

# Minimum Distance to Collision




Sumber : Montewka, 2011

# Minimum Distance to Collision

Kandidat terjadi *collision* pada tiga kondisi, dapat ditentukan melalui persamaan :

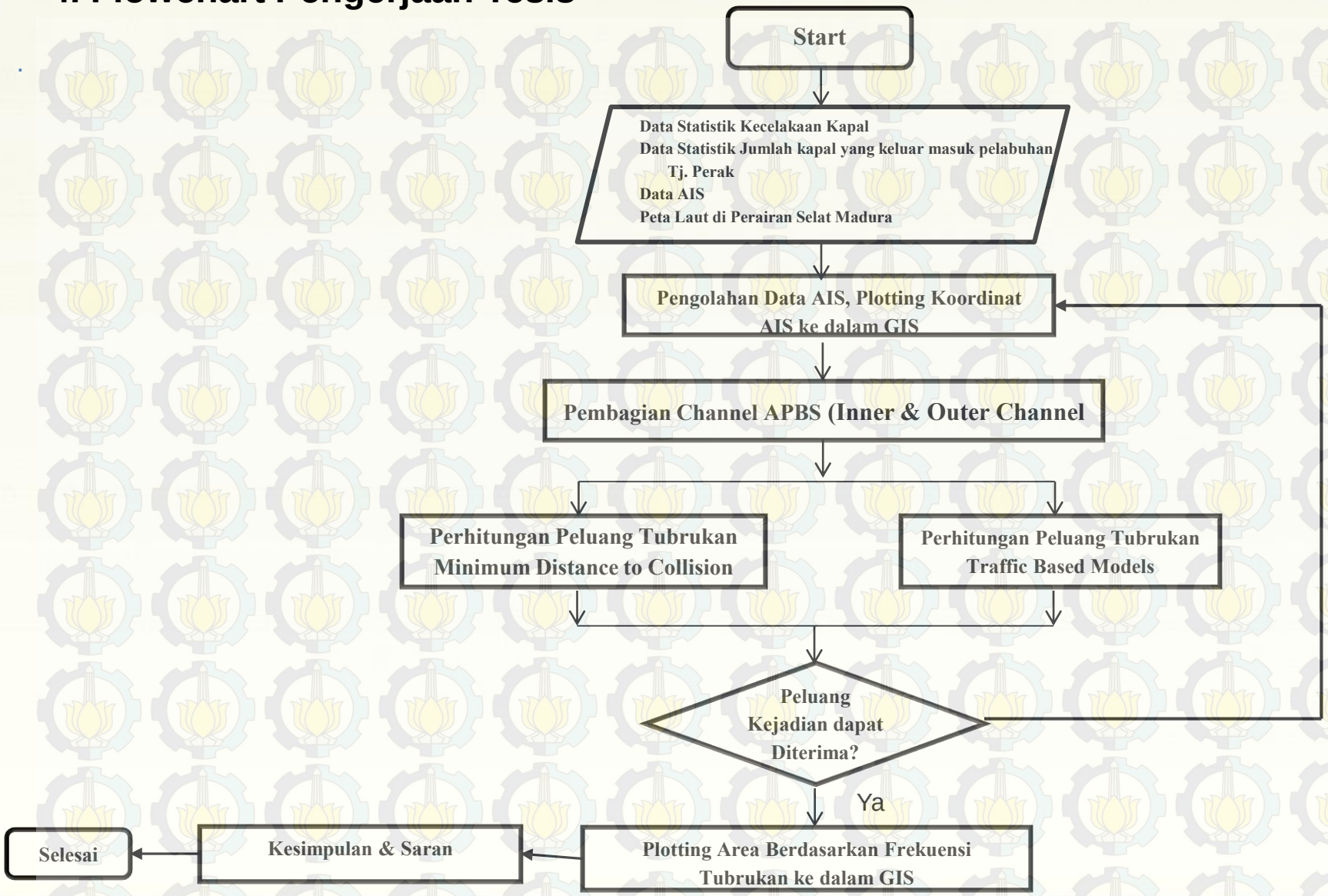
a.) $N_{head\ on} = T_0 P_0$ b.) $N_{overtaking} = T_0 P_0$ c.) $N_{crossing} = \Sigma_{ij} \frac{E[V_{ij}]\lambda_i \lambda_j}{V_i V_j sin\alpha}$

* $\boldsymbol{T_0 = \frac{N^2}{2L} E[V_{ij}]}$
* $E[V_{ij}] = \sqrt{(V_i{}^2 + V_j{}^2 - 2V_i V_j \cos\theta}$
* $\boldsymbol{P_0 = P, x \leq \frac{B_1 + B_2}{2}}$

Dimana :

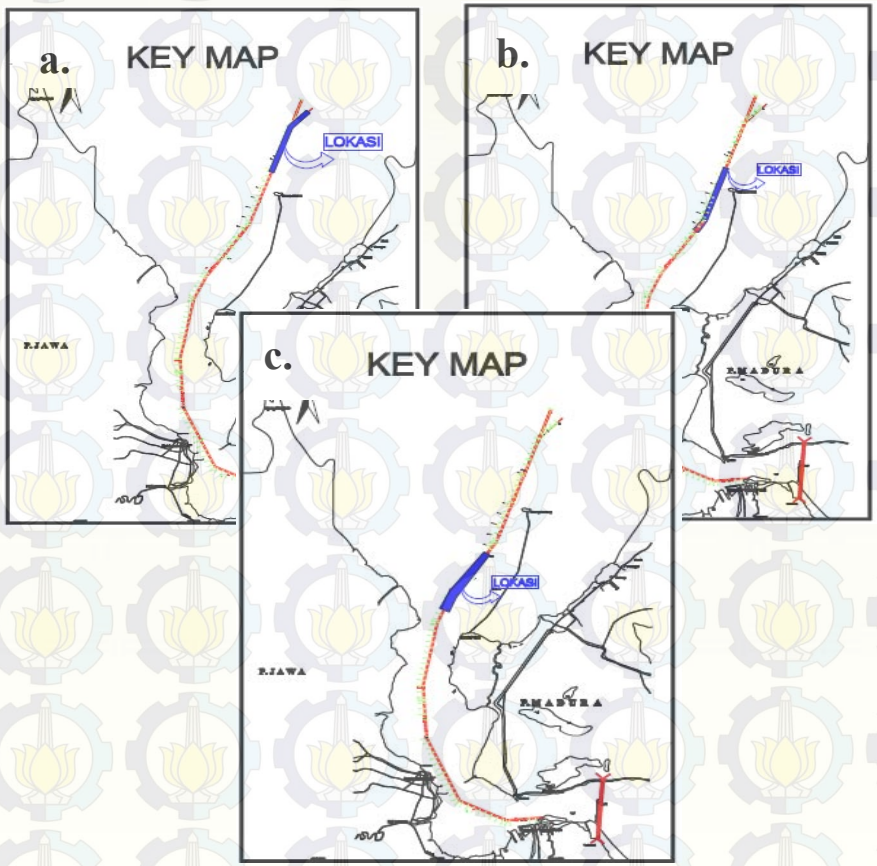
| | |
|---|---|
| $P_0$ | : peluang kapal tertubruk kapal lain secara *head on / overtaking / crossing* |
| $N$ | : perkiraan jumlah kapal yang lewat |
| $L$ | : panjang lintasan / selat yang dilalui |
| $E[V_{ij}]$ | : kecepatan relatif kapal |
| $i$ | : kapal pertama |
| $j$ | : kapal kedua |
| $\lambda$ | : intensitas kapal yang melalui selat |
| $V$ | : kecepatan kapal |
| $\alpha$ | : sudut diantara dua kapal yang akan bertemu |

# 4. Flowchart Pengerjaan Tesis

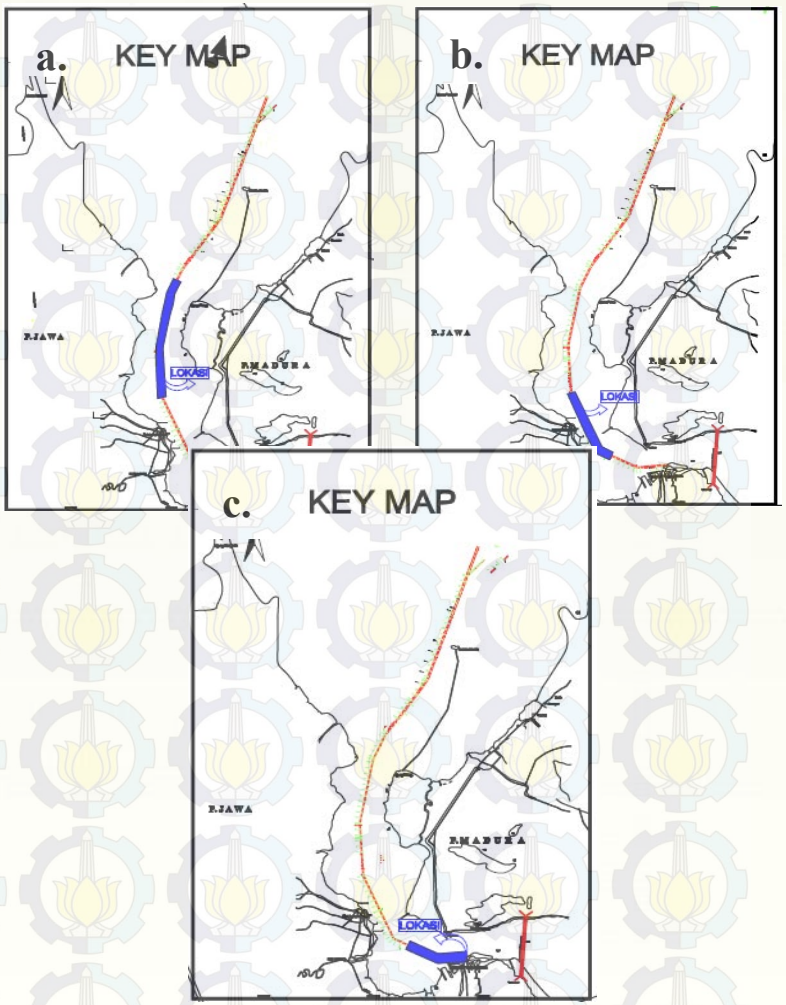


# 5. PERHITUNGAN PELUANG TUBRUKAN KAPAL

## Pembagian Channel APBS




**Outer Channel APBS**
**(a) 0-6500 (b) 6500-13.000 (c) 13.000-19.000**
(Sumber : Pelindo, 2011)



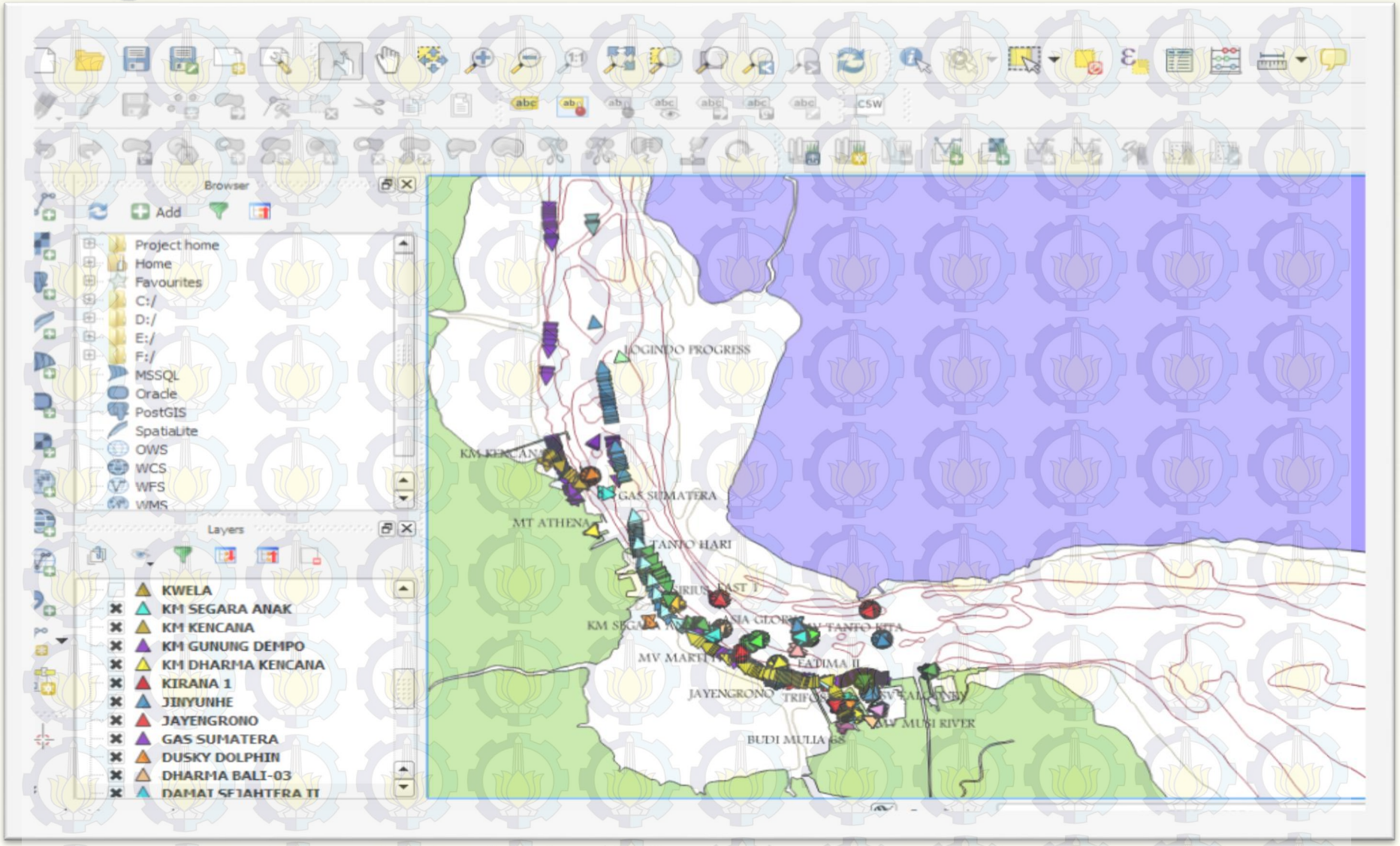

**Inner Channel APBS**
**(a) 19.000-30.000 (b) 30.000-38.000 (c) 38.000-43.000**
(Sumber : Pelindo, 2011)

# Contoh Data AIS (31 Januari 2014)

| Date | Received Time | Messg ID | Repeat Indicator | MMSI | Navi Status | Rate of Turn | Speed Over Ground | Position Accuracy | Longitude | Latitude | Course Over Ground | True Heading | Regional Appl | RAIMflag | UTC Direct | Remaining Frame | UTC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14/01/31 | 6:00:00 | 1 | 0 | 525019623 | 0 | 0 | 0 | 0 | 112.731 | -7.2 | 220 | 83 | 0 | 0 | 0 | 1 | 11:04:18 PM |
| 14/01/31 | 6:00:01 | 1 | 0 | 525016081 | 0 | -999.9 | 0.1 | 0 | 112.714608 | -7.18514 | 309.4 | 511 | 0 | 0 | 1 | 7 | 12:31:22 AM |
| 14/01/31 | 6:00:02 | 1 | 0 | 525016148 | 0 | -720 | 0.2 | 0 | 112.73375 | -7.185838 | 100.2 | 263 | 0 | 0 | 0 | 1 | 11:04:24 PM |
| 14/01/31 | 6:00:03 | 1 | 0 | 525013018 | 0 | 0 | 0.1 | 0 | 112.66638 | -7.143007 | 207.3 | 330 | 0 | 0 | 0 | 4 | 2:52:26 AM |
| 14/01/31 | 6:00:04 | 1 | 0 | 525015378 | 0 | -999.9 | 0 | 0 | 112.709592 | -7.192475 | 69.6 | 511 | 0 | 1 | 0 | 5 | 12:29:25 AM |
| 14/01/31 | 6:00:04 | 1 | 0 | 525007018 | 0 | 720 | 12.3 | 0 | 112.66116 | -7.053328 | 198.2 | 222 | 0 | 0 | 0 | 4 | 3:00:27 AM |
| 14/01/31 | 6:00:05 | 1 | 0 | 525016663 | 0 | -999.9 | 0 | 0 | 112.714205 | -7.182082 | 167.6 | 511 | 0 | 0 | 0 | 3 | 12:34:25 AM |
| 14/01/31 | 6:00:05 | 1 | 0 | 525025065 | 0 | 0 | 0.1 | 0 | 112.70539 | -7.1858 | 184 | 341 | 0 | 1 | 0 | 0 | 4:54:27 AM |
| 14/01/31 | 6:00:06 | 1 | 0 | 525025041 | 0 | -999.9 | 0 | 0 | 112.730742 | -7.206853 | 296.9 | 511 | 0 | 0 | 0 | 2 | 4:06:48 AM |
| 14/01/31 | 6:00:06 | 1 | 0 | 353241000 | 0 | 0 | 0 | 0 | 112.70885 | -7.196883 | 103 | 101 | 0 | 0 | 0 | 2 | 2:09:29 AM |
| 14/01/31 | 6:00:06 | 1 | 0 | 525025010 | 8 | -999.9 | 0 | 0 | 112.732202 | -7.204248 | 280 | 511 | 0 | 1 | 0 | 5 | 12:29:26 AM |
| 14/01/31 | 6:00:06 | 1 | 0 | 525008004 | 0 | 0 | 0 | 0 | 112.744443 | -7.194007 | 57.9 | 258 | 0 | 0 | 0 | 0 | 5:01:28 AM |
| 14/01/31 | 6:00:07 | 1 | 0 | 525024058 | 0 | 0 | 0 | 0 | 112.666462 | -7.157665 | 265 | 154 | 0 | 1 | 0 | 1 | 11:04:29 PM |
| 14/01/31 | 6:00:07 | 1 | 0 | 525005054 | 0 | 0 | 0 | 0 | 112.733438 | -7.196228 | 265.2 | 259 | 0 | 0 | 0 | 1 | 11:04:43 PM |
| 14/01/31 | 6:00:08 | 1 | 0 | 441726000 | 0 | 0 | 102.3 | 0 | 181 | 91 | 360 | 0 | 0 | 0 | 1 | 2 | 2:31:03 AM |
| 14/01/31 | 6:00:09 | 1 | 0 | 235060356 | 0 | -2.2 | 0 | 0 | 112.7142 | -7.188517 | 349.3 | 259 | 0 | 0 | 0 | 6 | 2:38:30 AM |
| 14/01/31 | 6:00:10 | 3 | 0 | 525005054 | 0 | 0 | 0 | 0 | 112.733438 | -7.196228 | 265.2 | 259 | 0 | 0 | 0 | 1 | 11:04:43 PM |

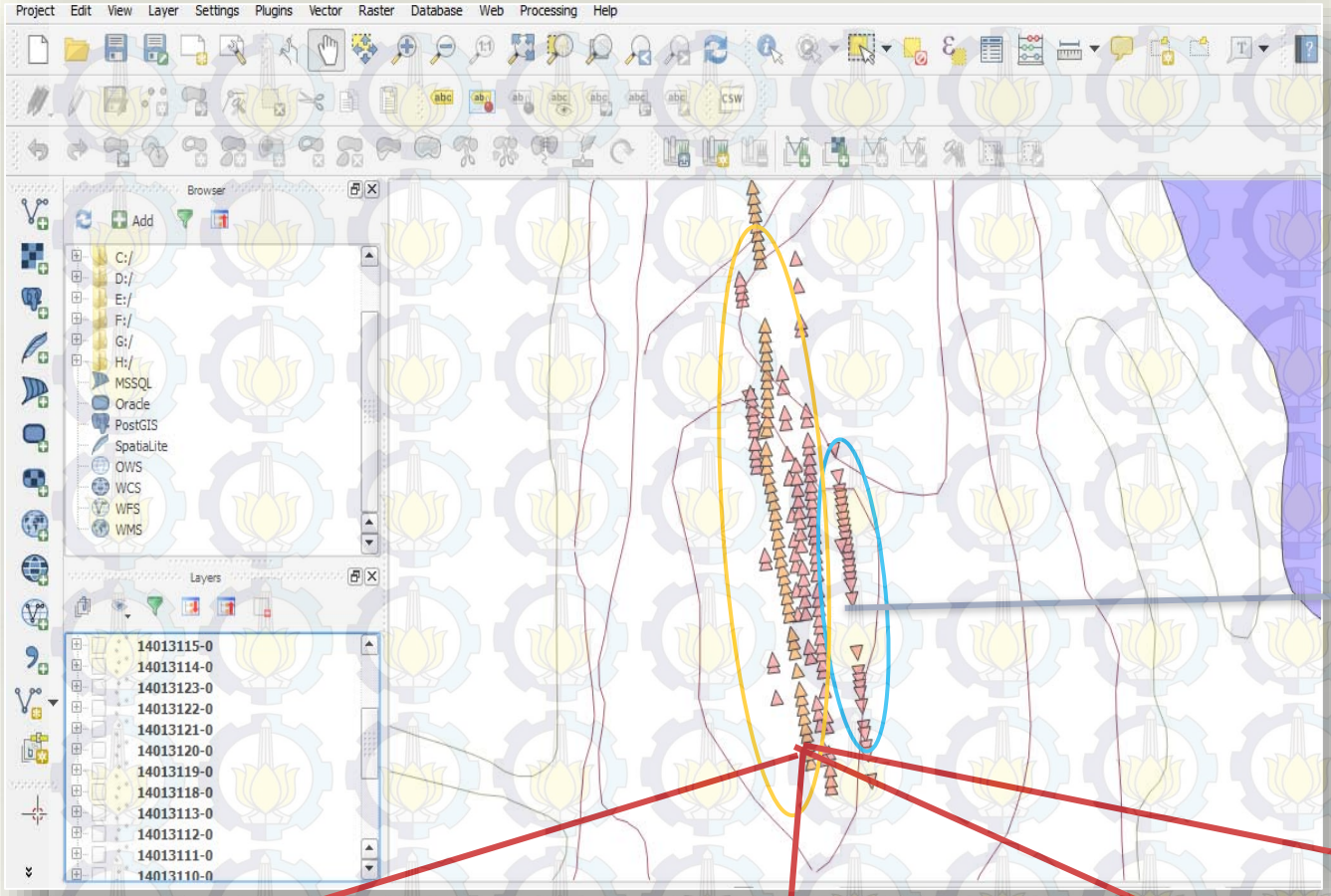
**Input Data AIS untuk Perhitungan**

# Plotting Area ke GIS



# A. Traffic Based Models

# Skenario Head On Collision




**Data Kapal :**

| | |
|---|---|
| **Target Ship** | : Adinda Fadilla |
| L | : 82 meter |
| B | : 21 meter |
| V | : 6.5 knot |
| Tipe | : Deck Cargo Ship |
| MMSI | : 525018110 |

| | |
|---|---|
| **Own Ship-1** | : Damai Sejahtera II |
| L | : 120 meter |
| B | : 22 meter |
| V | : 8.7 knot |
| Tipe | : Container Ship |
| MMSI | : 525003137 |

| | |
|---|---|
| **Own Ship-2** | : Gunung Dempo |
| L | : 147 meter |
| B | : 23 meter |
| V | : 13.9 knot |
| Tipe | : Passenger Ship |
| MMSI | : 525005054 |

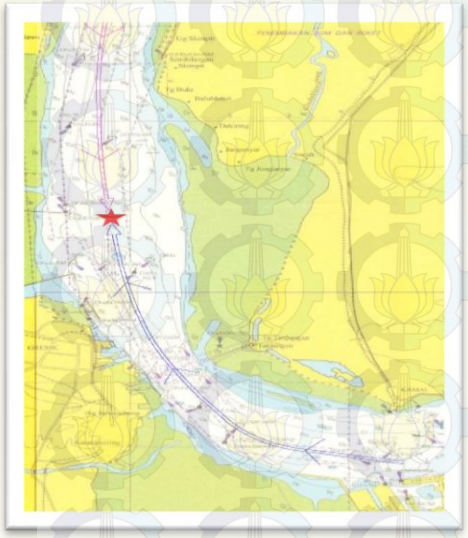
| | |
|---|---|
| **Own Ship-3** | : Kwela |
| L | : 120 meter |
| B | : 22 meter |
| V | : 8.7 knot |
| Tipe | : Bulk Carrier |
| MMSI | : 355866000 |

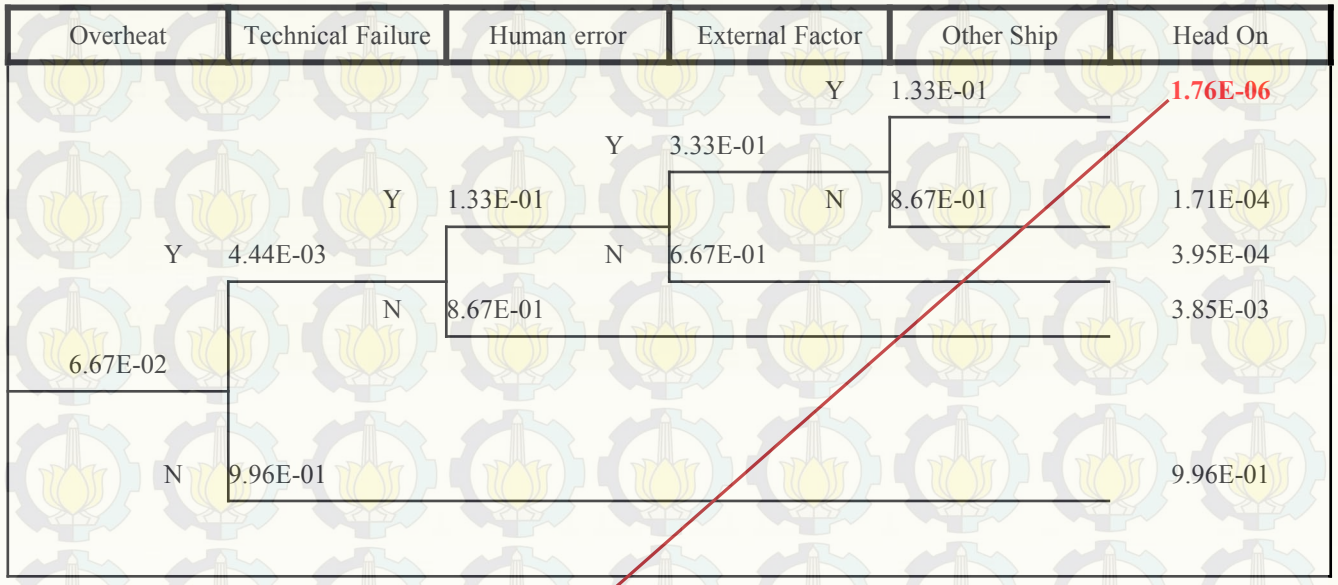
| | |
|---|---|
| **Own Ship-4** | : Tanto Sayang |
| L | : 105 meter |
| B | : 19 meter |
| V | : 6.8 knot |
| Tipe | : Container Ship |
| MMSI | : 525016079 |

# Head On Collision

## Outer Channel

Skenario Head On Collision






| | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | D mtr | ρ ships/m2 | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outer Channel-Head On | 0-6500 | 5.1272 | 3.341 | 23 | 21 | 4 | 100 | 6523 | 0.0078 | 1.76E-06 | 11.069 | 1.94E-05 | 0.681 |
| | 6500-13000 | 5.1272 | 3.341 | 23 | 21 | 4 | 100 | 6486 | 0.0078 | 1.76E-06 | 11.007 | 1.93E-05 | 0.677 |
| | 13000-19000 | 5.1272 | 3.341 | 23 | 21 | 4 | 100 | 6009 | 0.0078 | 1.76E-06 | 10.197 | 1.79E-05 | 0.627 |
| Outer Channel-Head On | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | D mtr | ρ ships/m2 | $P_c$ | Ni | Pa | Na acc/year |
| | 0-6500 | 5.1272 | 3.341 | 23 | 21 | 4 | 150 | 6523 | 0.0052 | 1.76E-06 | 4.920 | 8.64E-06 | 0.303 |
| | 6500-13000 | 5.1272 | 3.341 | 23 | 21 | 4 | 150 | 6486 | 0.0052 | 1.76E-06 | 4.892 | 8.59E-06 | 0.301 |
| | 13000-19000 | 5.1272 | 3.341 | 23 | 21 | 4 | 150 | 6009 | 0.0052 | 1.76E-06 | 4.532 | 7.96E-06 | 0.279 |
| Outer Channel-Head On | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | D mtr | ρ ships/m2 | $P_c$ | Ni | Pa | Na acc/year |
| | 0-6500 | 5.1272 | 3.341 | 23 | 21 | 4 | 200 | 6523 | 0.0039 | 1.76E-06 | 2.767 | 4.86E-06 | 0.170 |
| | 6500-13000 | 5.1272 | 3.341 | 23 | 21 | 4 | 200 | 6486 | 0.0039 | 1.76E-06 | 2.752 | 4.83E-06 | 0.169 |
| | 13000-19000 | 5.1272 | 3.341 | 23 | 21 | 4 | 200 | 6009 | 0.0039 | 1.76E-06 | 2.549 | 4.48E-06 | 0.157 |

Next

# Head On Collision
## Inner Channel

| Inner Channel-Head On | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | D mtr | ρ ships/m2 | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19000-30000 | 5.1272 | 3.34 | 23 | 21 | 4 | **100** | 11024.3 | 0.0078 | **1.76E-06** | 13.708 | 2.41E-05 | **0.843** |
| | 30000-38000 | 5.1272 | 3.34 | 23 | 21 | 4 | **100** | 8057.5 | 0.0078 | **1.76E-06** | 8.673 | 1.52E-05 | **0.534** |
| | 38000-43000 | 5.1272 | 3.34 | 23 | 21 | 4 | **100** | 5028.6 | 0.0078 | **1.76E-06** | 3.533 | 6.20E-06 | **0.217** |

| Inner Channel-Head On | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | D mtr | ρ ships/m2 | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19000-30000 | 5.1272 | 3.34 | 23 | 21 | 4 | **150** | 11024.3 | 0.0052 | **1.76E-06** | 8.315 | 1.46E-05 | **0.512** |
| | 30000-38000 | 5.1272 | 3.34 | 23 | 21 | 4 | **150** | 8057.5 | 0.0052 | **1.76E-06** | 6.077 | 1.07E-05 | **0.374** |
| | 38000-43000 | 5.1272 | 3.34 | 23 | 21 | 4 | **150** | 5028.6 | 0.0052 | **1.76E-06** | 3.793 | 6.66E-06 | **0.233** |

| Inner Channel-Head On | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | D mtr | ρ ships/m2 | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19000-30000 | 5.1272 | 3.34 | 23 | 21 | 4 | **200** | 11024.3 | 0.0039 | **1.76E-06** | 4.677 | 8.21E-06 | **0.288** |
| | 30000-38000 | 5.1272 | 3.34 | 23 | 21 | 4 | **200** | 8057.5 | 0.0039 | **1.76E-06** | 3.418 | 6.00E-06 | **0.210** |
| | 38000-43000 | 5.1272 | 3.34 | 23 | 21 | 4 | **200** | 5028.6 | 0.0039 | **1.76E-06** | 2.133 | 3.75E-06 | **0.131** |

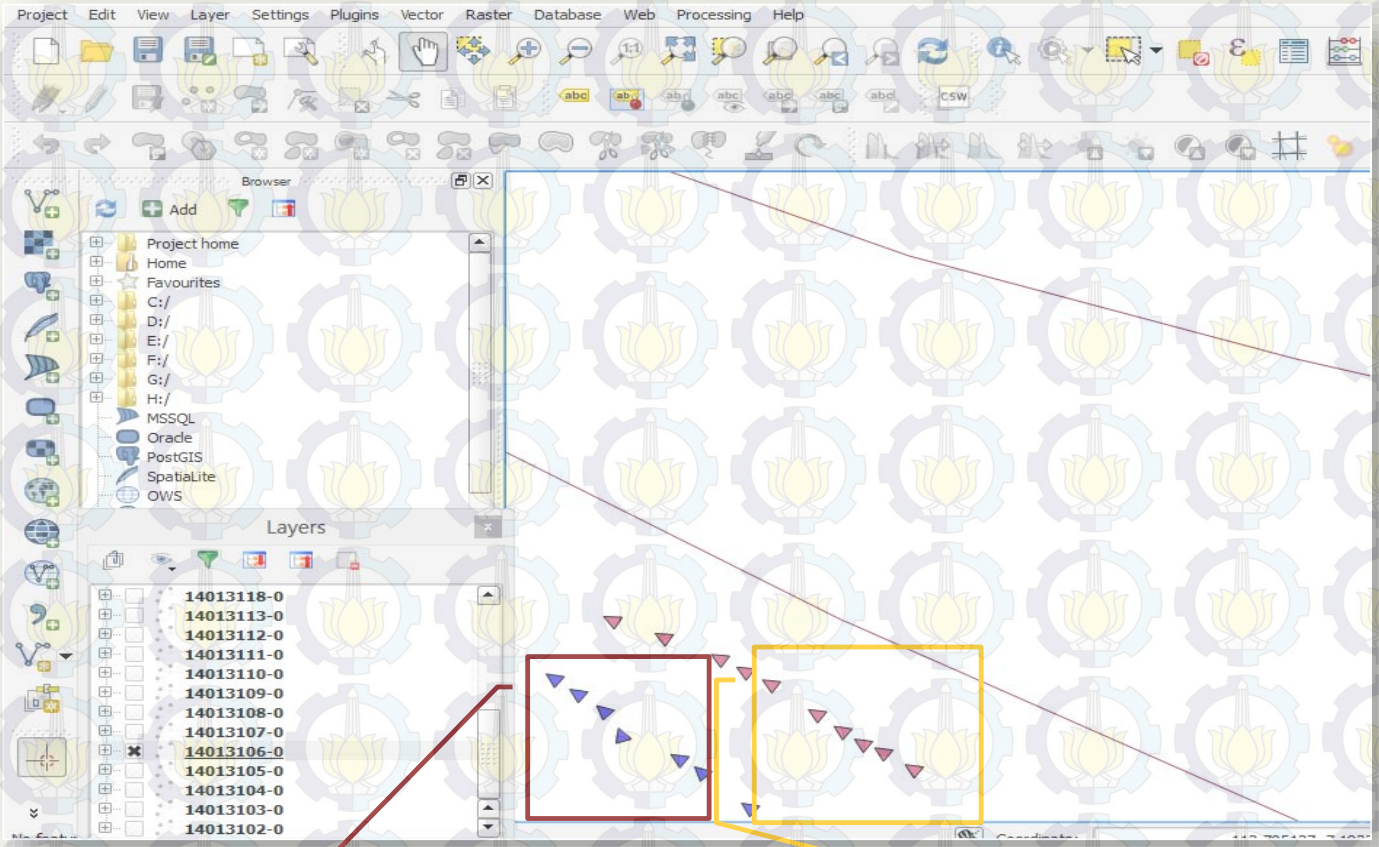
## Summary

| Head On Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | **100** | 0-6500 | **0.681** | 19000-30000 | **1.151** |
| | **100** | 6500-13000 | **0.677** | 30000-38000 | **0.841** |
| | **100** | 13000-19000 | **0.627** | 38000-43000 | **0.525** |
| | | Total | **1.986** | | **2.517** |

| Head On Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | **150** | 0-6500 | **0.303** | 19000-30000 | **0.512** |
| | **150** | 6500-13000 | **0.301** | 30000-38000 | **0.374** |
| | **150** | 13000-19000 | **0.279** | 38000-43000 | **0.233** |
| | | Total | **0.882** | | **1.119** |

| Head On Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | **200** | 0-6500 | **0.170** | 19000-30000 | **0.288** |
| | **200** | 6500-13000 | **0.169** | 30000-38000 | **0.210** |
| | **200** | 13000-19000 | **0.157** | 38000-43000 | **0.131** |
| | | Total | **0.496** | | **0.629** |

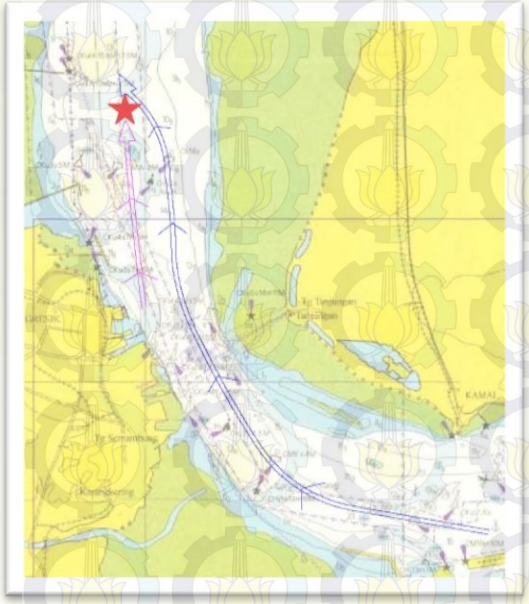
# Overtaking Collision



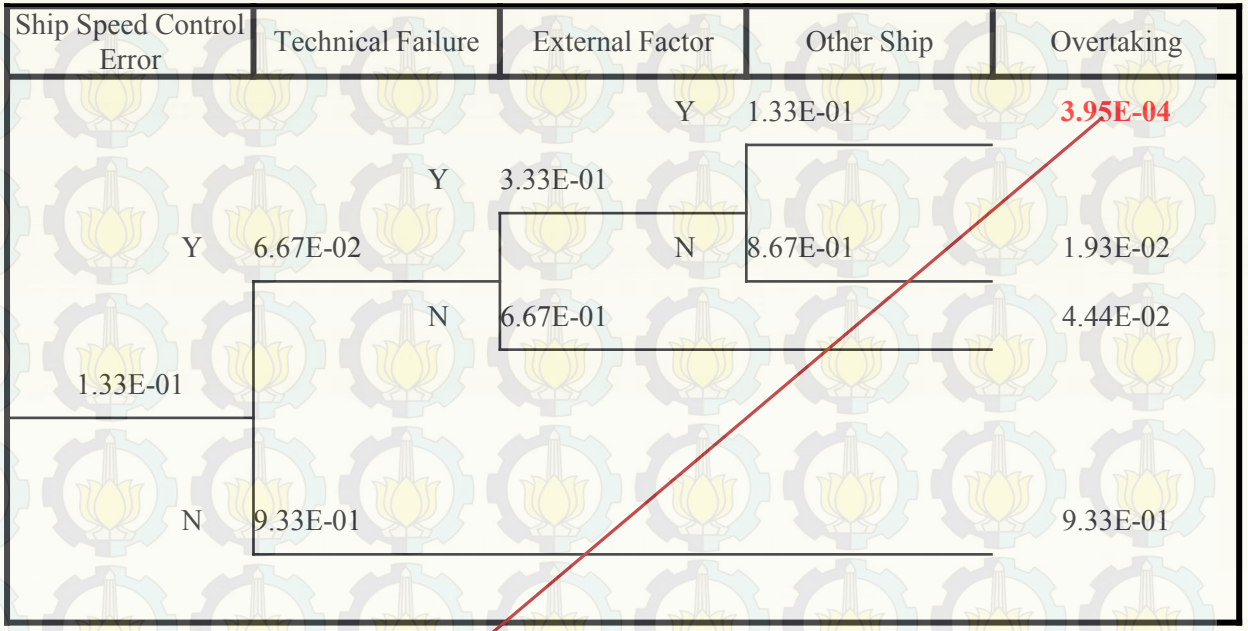

## Data Kapal

| | | | |
|---|---|---|---|
| **Target Ship** | : Jinyunhe | **Own Ship** | : Dharma Bali-03 |
| L | : 172 meter | L | : 29 meter |
| B | : 28 meter | B | : 10 meter |
| V | : 5.1 knot | V | : 5.5 knot |
| Tipe | : Container Ship | Tipe | : Container Ship |
| MMSI | : 353241000 | MMSI | : 525016079 |

# Overtaking Collision
## Outer Channel



Skenario Overtaking Collision




| | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overtaking-Outer Channel | 0-6500 | 2.827 | 2.6214 | 10 | 28 | 2 | 100 | 0.00707 | 6522.9 | 3.95E-04 | 0.04865108 | 1.92E-05 | 0.168 |
| | 6500-13000 | 2.827 | 2.6214 | 10 | 28 | 2 | 100 | 0.00707 | 6486 | 3.95E-04 | 0.04837586 | 1.91E-05 | 0.167 |
| | 13000-19000 | 2.827 | 2.6214 | 10 | 28 | 2 | 100 | 0.00707 | 6009.2 | 3.95E-04 | 0.04481965 | 1.77E-05 | 0.155 |

| | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overtaking-Outer Channel | 0-6500 | 2.827 | 2.6214 | 10 | 28 | 2 | 150 | 0.00472 | 6522.9 | 3.95E-04 | 0.02162270 | 8.54E-06 | 0.075 |
| | 6500-13000 | 2.827 | 2.6214 | 10 | 28 | 2 | 150 | 0.00472 | 6486 | 3.95E-04 | 0.02150038 | 8.49E-06 | 0.074 |
| | 13000-19000 | 2.827 | 2.6214 | 10 | 28 | 2 | 150 | 0.00472 | 6009.2 | 3.95E-04 | 0.01991984 | 7.87E-06 | 0.069 |

| | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overtaking-Outer Channel | 0-6500 | 2.827 | 2.6214 | 10 | 28 | 2 | 200 | 0.00354 | 6522.9 | 3.95E-04 | 0.01216277 | 4.81E-06 | 0.042 |
| | 6500-13000 | 2.827 | 2.6214 | 10 | 28 | 2 | 200 | 0.00354 | 6486 | 3.95E-04 | 0.01209397 | 4.78E-06 | 0.042 |
| | 13000-19000 | 2.827 | 2.6214 | 10 | 28 | 2 | 200 | 0.00354 | 6009.2 | 3.95E-04 | 0.01120491 | 4.43E-06 | 0.039 |

Next

# Overtaking Collision

## Inner Channel

| Overtaking-Inner Channel | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19000-30000 | 2.827 | 2.6214 | 10 | 28 | 2 | 100 | 0.00707464 | 11024.3 | 3.95E-04 | 0.0822248 | 3.25E-05 | 0.285 |
| | 30000-38000 | 2.827 | 2.6214 | 10 | 28 | 2 | 100 | 0.00707464 | 8057.5 | 3.95E-04 | 0.0600969 | 2.37E-05 | 0.208 |
| | 38000-43000 | 2.827 | 2.6214 | 10 | 28 | 2 | 100 | 0.00707464 | 5028.6 | 3.95E-04 | 0.0375058 | 1.48E-05 | 0.130 |

| Overtaking-Inner Channel | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19000-30000 | 2.827 | 2.6214 | 10 | 28 | 2 | 150 | 0.00471642 | 11024.3 | 3.95E-04 | 0.0365444 | 1.44E-05 | 0.253 |
| | 30000-38000 | 2.827 | 2.6214 | 10 | 28 | 2 | 150 | 0.00471642 | 8057.5 | 3.95E-04 | 0.0267097 | 1.06E-05 | 0.185 |
| | 38000-43000 | 2.827 | 2.6214 | 10 | 28 | 2 | 150 | 0.00471642 | 5028.6 | 3.95E-04 | 0.0166693 | 6.59E-06 | 0.115 |

| Overtaking-Inner Channel | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | $P_c$ | Ni | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 19000-30000 | 2.827 | 2.6214 | 10 | 28 | 2 | 200 | 0.00353732 | 11024.3 | 3.95E-04 | 0.0205562 | 7.31E-06 | 0.128 |
| | 30000-38000 | 2.827 | 2.6214 | 10 | 28 | 2 | 200 | 0.00353732 | 8057.5 | 3.95E-04 | 0.0150242 | 5.34E-06 | 0.094 |
| | 38000-43000 | 2.827 | 2.6214 | 10 | 28 | 2 | 200 | 0.00353732 | 5028.6 | 3.95E-04 | 0.0093765 | 3.33E-06 | 0.058 |

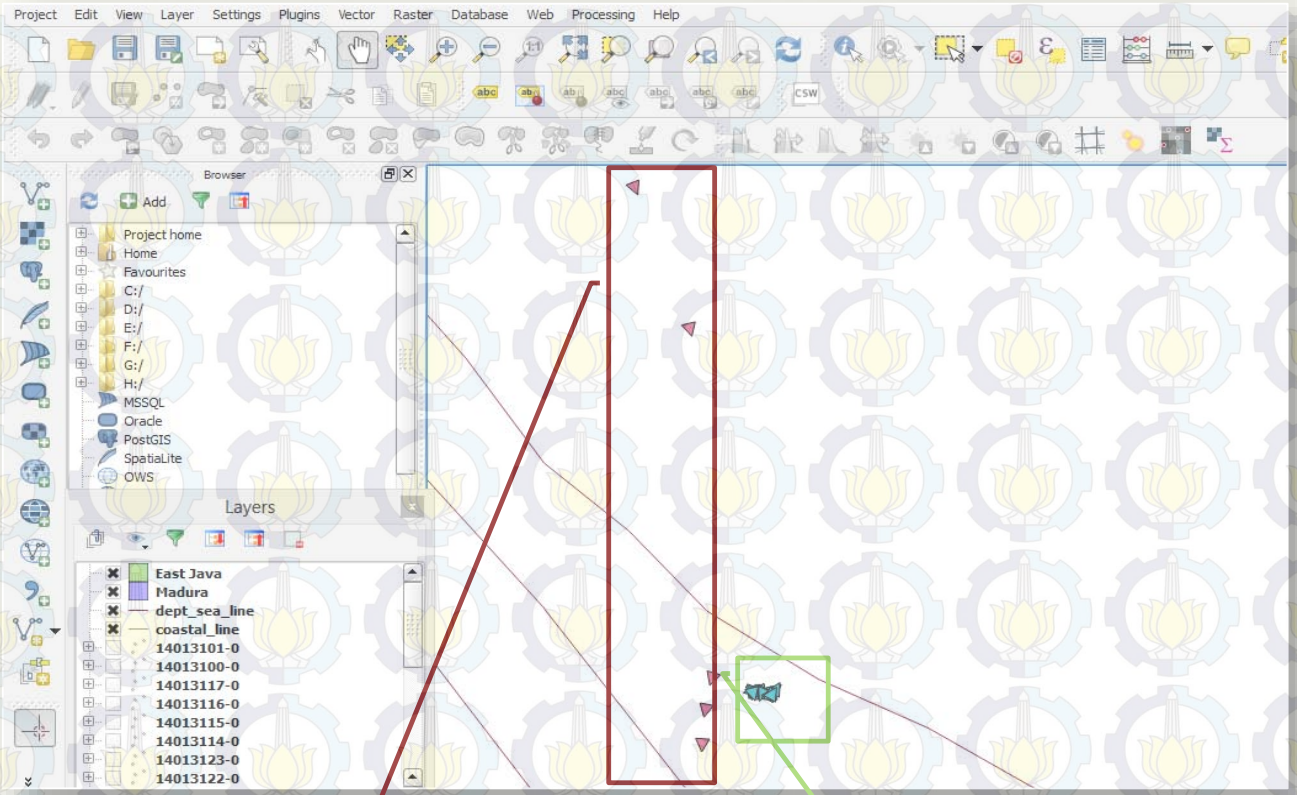
## Summary

| Overtaking Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | 100 | 0-6500 | 0.168 | 19000-30000 | 0.285 |
| | 100 | 6500-13000 | 0.167 | 30000-38000 | 0.208 |
| | 100 | 13000-19000 | 0.155 | 38000-43000 | 0.130 |
| | | Total | 0.491 | | 0.622 |

| Overtaking Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | 200 | 0-6500 | 0.042 | 19000-30000 | 0.142 |
| | 200 | 6500-13000 | 0.042 | 30000-38000 | 0.104 |
| | 200 | 13000-19000 | 0.039 | 38000-43000 | 0.065 |
| | | Total | 0.123 | | 0.311 |

| Overtaking Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | 150 | 0-6500 | 0.075 | 19000-30000 | 0.253 |
| | 150 | 6500-13000 | 0.074 | 30000-38000 | 0.185 |
| | 150 | 13000-19000 | 0.069 | 38000-43000 | 0.115 |
| | | Total | 0.218 | | 0.553 |

# Crossing Collision



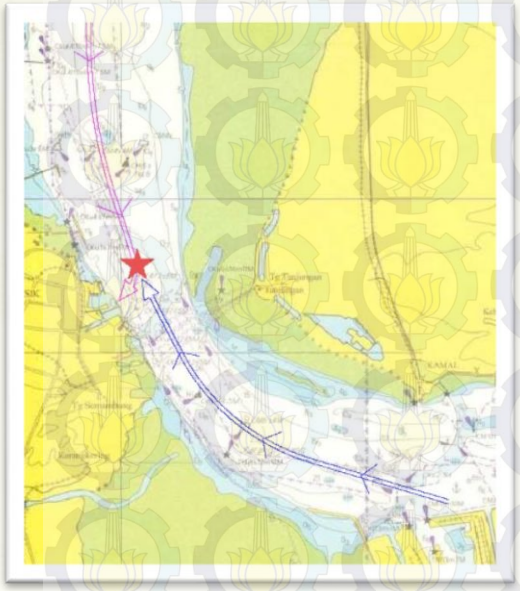

**Data Kapal**

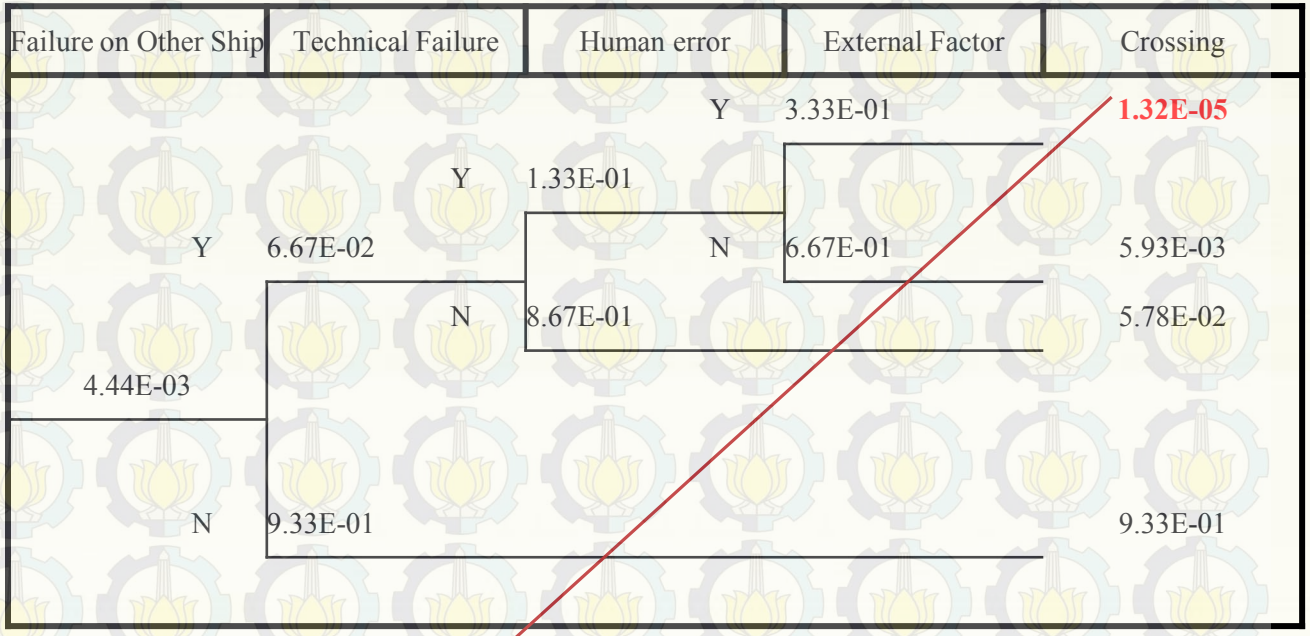
| | |
|---|---|
| **Own Ship** | : Tanto Hari |
| L | : 126 meter |
| B | : 20 meter |
| V | : 6.3 knot |
| Tipe | : General Cargo |
| MMSI | : 525015966 |

| | |
|---|---|
| **Target Ship** | : Sirius |
| L | : 80 meter |
| B | : 14 meter |
| V | : 11.6 knot |
| Tipe | : Chemical Oil Tanker |
| MMSI | : 525023202 |

# Crossing Collision
## Outer Channel

Skenario Overtaking Collision






| Outer Channel-Crossing | Spot | V1 | V2 | B1 | B2 | Nm | W | ρ | D | Pc | Pi | Pa | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m/s | m/s | mtr | mtr | ship/hr | mtr | ships/m2 | mtr | | | | acc/year |
| | 0-6500 | 3.2382 | 5.9624 | 20 | 14 | 2 | 100 | 3.33E-06 | 6522.9 | 1.32E-05 | 1.2119 | 1.60E-05 | 0.280 |
| | 6500-13000 | 3.2382 | 5.9624 | 20 | 14 | 2 | 100 | 3.33E-06 | 6486 | 1.32E-05 | 1.2050 | 1.59E-05 | 0.278 |
| | 13000-19000 | 3.2382 | 5.9624 | 20 | 14 | 2 | 100 | 3.33E-06 | 6009.2 | 1.32E-05 | 1.1164 | 1.47E-05 | 0.258 |

| Outer Channel-Crossing | Spot | V1 | V2 | B1 | B2 | Nm | W | ρ | D | Pc | Pi | Pa | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m/s | m/s | mtr | mtr | ship/hr | mtr | ships/m2 | mtr | | | | acc/year |
| | 0-6500 | 3.2382 | 5.9624 | 20 | 14 | 2 | 150 | 2.22E-06 | 6522.9 | 1.32E-05 | 0.8079 | 1.06E-05 | 0.186 |
| | 6500-13000 | 3.2382 | 5.9624 | 20 | 14 | 2 | 150 | 2.22E-06 | 6486 | 1.32E-05 | 0.8034 | 1.06E-05 | 0.185 |
| | 13000-19000 | 3.2382 | 5.9624 | 20 | 14 | 2 | 150 | 2.22E-06 | 6009.2 | 1.32E-05 | 0.7443 | 9.80E-06 | 0.172 |

| Outer Channel-Crossing | Spot | V1 | V2 | B1 | B2 | Nm | W | ρ | D | Pc | Pi | Pa | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m/s | m/s | mtr | mtr | ship/hr | mtr | ships/m2 | mtr | | | | acc/year |
| | 0-6500 | 3.2382 | 5.9624 | 20 | 14 | 2 | 200 | 1.67E-06 | 6522.9 | 1.32E-05 | 0.60594 | 7.98E-06 | 0.140 |
| | 6500-13000 | 3.2382 | 5.9624 | 20 | 14 | 2 | 200 | 1.67E-06 | 6486 | 1.32E-05 | 0.60252 | 7.93E-06 | 0.139 |
| | 13000-19000 | 3.2382 | 5.9624 | 20 | 14 | 2 | 200 | 1.67E-06 | 6009.2 | 1.32E-05 | 0.55822 | 7.35E-06 | 0.129 |

Next

# Crossing Collision
## Inner Channel

| Inner Channel-Crossing | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | Pc | Pi | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-6500 | 3.2382 | 5.9624 | 20 | 14 | 2 | **100** | 3.33E-06 | 11024.3 | **1.32E-05** | 2.5114 | 3.31E-05 | 0.579 |
| | 6500-13000 | 3.2382 | 5.9624 | 20 | 14 | 2 | **100** | 3.33E-06 | 8057.5 | **1.32E-05** | 1.8356 | 2.42E-05 | 0.423 |
| | 13000-19000 | 3.2382 | 5.9624 | 20 | 14 | 2 | **100** | 3.33E-06 | 5028.6 | **1.32E-05** | 1.1456 | 1.51E-05 | 0.264 |

| Inner Channel-Crossing | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | Pc | Pi | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-6500 | 3.2382 | 5.9624 | 20 | 14 | 2 | **150** | 2.22E-06 | 11024.3 | **1.32E-05** | 1.6743 | 2.20E-05 | 0.386 |
| | 6500-13000 | 3.2382 | 5.9624 | 20 | 14 | 2 | **150** | 2.22E-06 | 8057.5 | **1.32E-05** | 1.2237 | 1.61E-05 | 0.282 |
| | 13000-19000 | 3.2382 | 5.9624 | 20 | 14 | 2 | **150** | 2.22E-06 | 5028.6 | **1.32E-05** | 0.7637 | 1.01E-05 | 0.176 |

| Inner Channel-Crossing | Spot | V1 m/s | V2 m/s | B1 mtr | B2 mtr | Nm ship/hr | W mtr | ρ ships/m2 | D mtr | Pc | Pi | Pa | Na acc/year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-6500 | 3.2382 | 5.9624 | 20 | 14 | 2 | **200** | 1.67E-06 | 11024.3 | **1.32E-05** | 1.2557 | 8.27E-06 | 0.145 |
| | 6500-13000 | 3.2382 | 5.9624 | 20 | 14 | 2 | **200** | 1.67E-06 | 8057.5 | **1.32E-05** | 0.9178 | 6.04E-06 | 0.106 |
| | 13000-19000 | 3.2382 | 5.9624 | 20 | 14 | 2 | **200** | 1.67E-06 | 5028.6 | **1.32E-05** | 0.5728 | 3.77E-06 | 0.066 |

## Summary

| Crossing Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | **100** | 0-6500 | **0.280** | 19000-30000 | **0.579** |
| | **100** | 6500-13000 | **0.278** | 30000-38000 | **0.423** |
| | **100** | 13000-19000 | **0.258** | 38000-43000 | **0.264** |
| | | Total | **0.815** | | **1.267** |

| Crossing Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | **200** | 0-6500 | **0.140** | 19000-30000 | **0.290** |
| | **200** | 6500-13000 | **0.139** | 30000-38000 | **0.212** |
| | **200** | 13000-19000 | **0.129** | 38000-43000 | **0.132** |
| | | Total | **0.408** | | **0.634** |

| Crossing Collision | W mtr | Outer Channel Spot | Na acc/year | Inner Channel Spot | Na acc/year |
|---|---|---|---|---|---|
| | **150** | 0-6500 | **0.186** | 19000-30000 | **0.386** |
| | **150** | 6500-13000 | **0.185** | 30000-38000 | **0.282** |
| | **150** | 13000-19000 | **0.172** | 38000-43000 | **0.176** |
| | | Total | **0.543** | | **0.845** |

# B. Minimum Distance To Collision

# Minimum Distance to Collision

| | Encounter | $V_1$ | $V_2$ | $N_{near\ coll}$ | N | L | cos α | $V_{12}$ | To | $B_1$ | $B_2$ | Po | $N_{coll}$ | Na | SHF | Pc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outer Channel Spot 0-6500 | Head On | 5.13 | 3.34 | 7.82E-02 | 35040 | 6522.9 | 0.983 | 1.881 | 1142.300 | 23 | 21 | 2.56E-02 | 29.2 | **0.75** | 2.68E-03 | 1.37E-03 |
| | Crossing | 3.24 | 5.97 | 2.08E-01 | 17520 | 6522.9 | 0.017 | 22.720 | 275.887 | 20 | 14 | 2.56E-02 | 7.1 | **0.18** | 2.95E-02 | 6.27E-02 |
| | Overtaking | 2.83 | 2.62 | 2.82E-04 | 17520 | 6522.9 | -0.707 | 12.694 | 154.139 | 10 | 28 | 2.56E-02 | 3.9 | **0.10** | 7.16E-05 | 2.72E-04 |

| | Encounter | $V_1$ | $V_2$ | $N_{near\ coll}$ | N | L | cos α | $V_{12}$ | To | $B_1$ | $B_2$ | Po | $N_{coll}$ | Na | SHF | Pc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outer Channel Spot 6500-13000 | Head On | 5.13 | 3.34 | 7.82E-02 | 35040 | 6486 | 0.983 | 1.881 | 1129.413 | 23 | 21 | 2.56E-02 | 28.9 | **0.74** | 2.71E-03 | 1.40E-03 |
| | Crossing | 3.24 | 5.97 | 2.08E-01 | 17520 | 6486 | 0.017 | 22.720 | 272.775 | 20 | 14 | 2.56E-02 | 7.0 | **0.18** | 2.99E-02 | 6.41E-02 |
| | Overtaking | 2.83 | 2.62 | 2.82E-04 | 17520 | 6486 | -0.707 | 12.694 | 152.400 | 10 | 28 | 2.56E-02 | 3.9 | **0.10** | 7.24E-05 | 2.78E-04 |

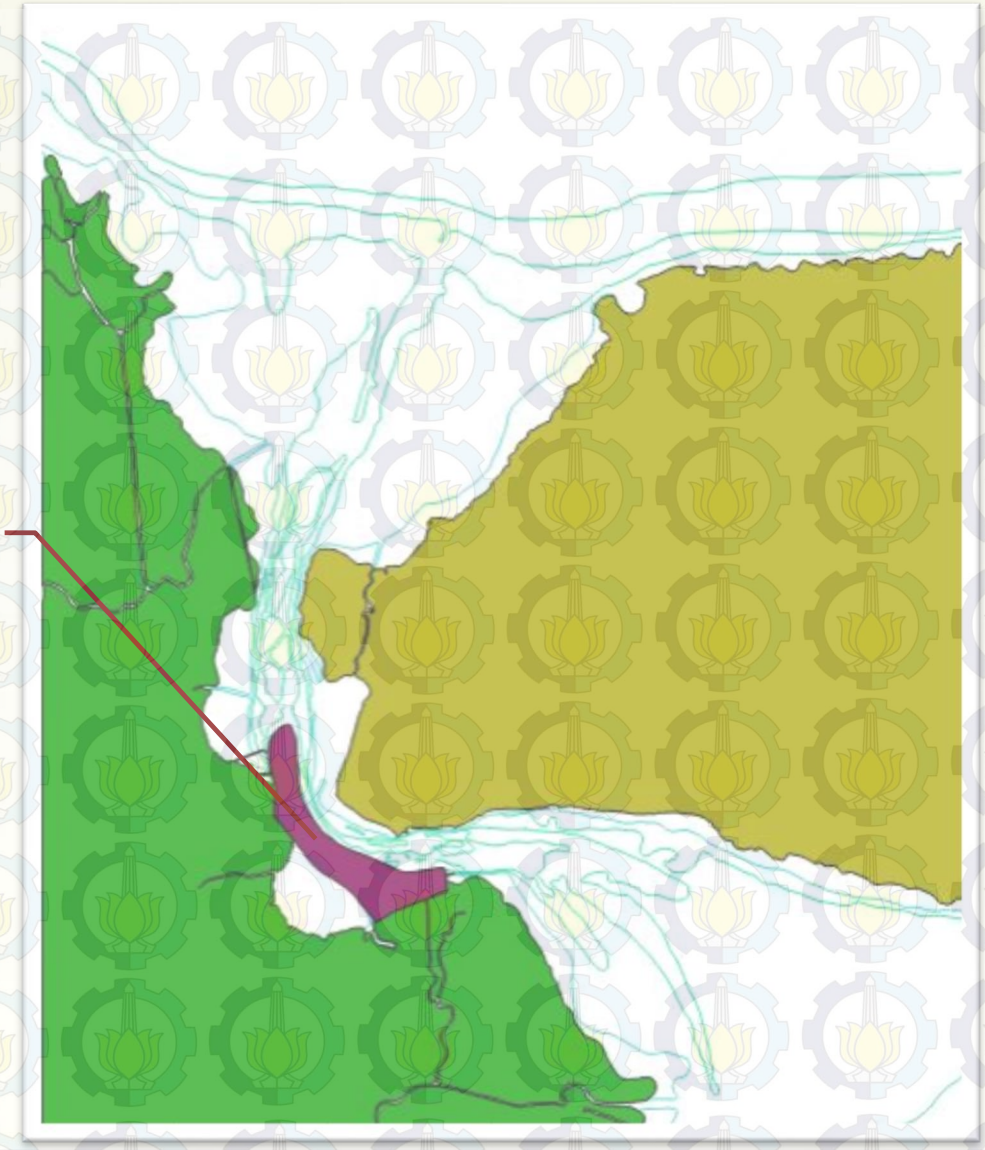
| | Encounter | $V_1$ | $V_2$ | $N_{near\ coll}$ | N | L | cos α | $V_{12}$ | To | $B_1$ | $B_2$ | Po | $N_{coll}$ | Na | SHF | Pc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outer Channel Spot 13000-19000 | Head On | 5.13 | 3.34 | 7.82E-02 | 35040 | 6009.2 | 0.983 | 1.881 | 969.465 | 23 | 21 | 2.56E-02 | 24.8 | **0.64** | 3.15E-03 | 1.91E-03 |
| | Crossing | 3.24 | 5.97 | 2.08E-01 | 17520 | 6009.2 | 0.017 | 22.720 | 234.144 | 20 | 14 | 2.56E-02 | 6.0 | **0.15** | 3.48E-02 | 8.70E-02 |
| | Overtaking | 2.83 | 2.62 | 2.82E-04 | 17520 | 6009.2 | -0.707 | 12.694 | 130.817 | 10 | 28 | 2.56E-02 | 3.3 | **0.09** | 8.44E-05 | 3.78E-04 |

| | Encounter | $V_1$ | $V_2$ | $N_{near\ coll}$ | N | L | cos α | $V_{12}$ | To | $B_1$ | $B_2$ | Po | $N_{coll}$ | Na | SHF | Pc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inner Channel Spot 19000-30000 | Head On | 5.13 | 3.34 | 7.82E-02 | 35040 | 11024.3 | 0.983 | 1.881 | 3262.878 | 23 | 21 | 2.56E-02 | 83.5 | **2.14** | 9.37E-04 | 1.68E-04 |
| | Crossing | 3.24 | 5.97 | 2.08E-01 | 17520 | 11024.3 | 0.017 | 22.720 | 788.047 | 20 | 14 | 2.56E-02 | 20.2 | **0.52** | 1.03E-02 | 7.68E-03 |
| | Overtaking | 2.83 | 2.62 | 2.82E-04 | 17520 | 11024.3 | -0.707 | 12.694 | 440.284 | 10 | 28 | 2.56E-02 | 11.3 | **0.29** | 2.51E-05 | 3.34E-05 |

| | Encounter | $V_1$ | $V_2$ | $N_{near\ coll}$ | N | L | cos α | $V_{12}$ | To | $B_1$ | $B_2$ | Po | $N_{coll}$ | Na | SHF | Pc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inner Channel Spot 30000-38000 | Head On | 5.13 | 3.34 | 7.82E-02 | 35040 | 8057.5 | 0.983 | 1.881 | 1743.008 | 23 | 21 | 2.56E-02 | 44.6 | **1.14** | 1.75E-03 | 5.89E-04 |
| | Crossing | 3.24 | 5.97 | 2.08E-01 | 17520 | 8057.5 | 0.017 | 22.720 | 420.970 | 20 | 14 | 2.56E-02 | 10.8 | **0.28** | 1.93E-02 | 2.69E-02 |
| | Overtaking | 2.83 | 2.62 | 2.82E-04 | 17520 | 8057.5 | -0.707 | 12.694 | 235.197 | 10 | 28 | 2.56E-02 | 6.0 | **0.15** | 4.69E-05 | 1.17E-04 |

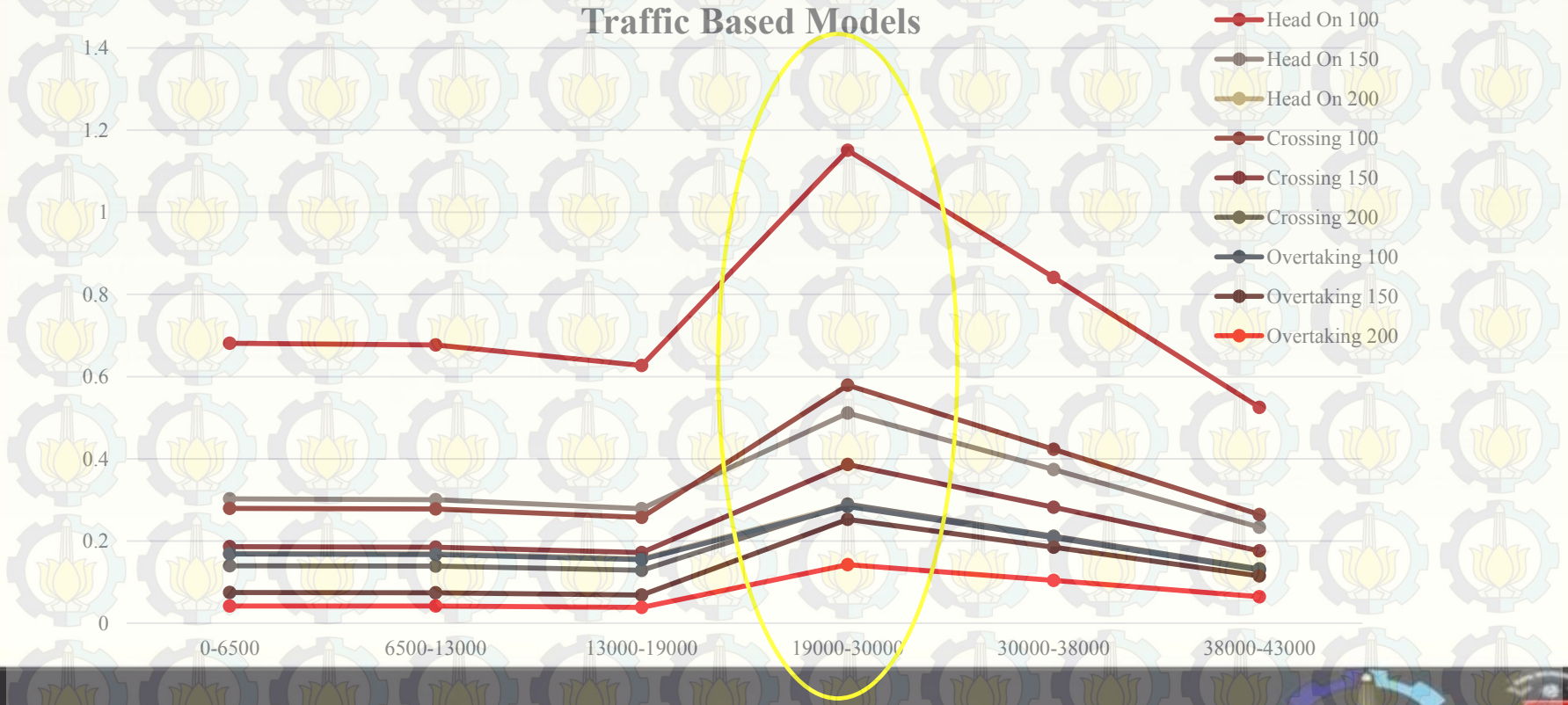
| | Encounter | $V_1$ | $V_2$ | $N_{near\ coll}$ | N | L | cos α | $V_{12}$ | To | $B_1$ | $B_2$ | Po | $N_{coll}$ | Na | SHF | Pc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inner Channel Spot 30000-38000 | Head On | 5.13 | 3.34 | 7.82E-02 | 35040 | 5028.6 | 0.983 | 1.881 | 678.880 | 23 | 21 | 2.56E-02 | 17.4 | **0.44** | 4.50E-03 | 3.89E-03 |
| | Crossing | 3.24 | 5.97 | 2.08E-01 | 17520 | 5028.6 | 0.017 | 22.720 | 163.962 | 20 | 14 | 2.56E-02 | 4.2 | **0.11** | 4.97E-02 | 1.77E-01 |
| | Overtaking | 2.83 | 2.62 | 2.82E-04 | 17520 | 5028.6 | -0.707 | 12.694 | 91.606 | 10 | 28 | 2.56E-02 | 2.3 | **0.06** | 1.20E-04 | 7.70E-04 |

# Plotting Area ke GIS



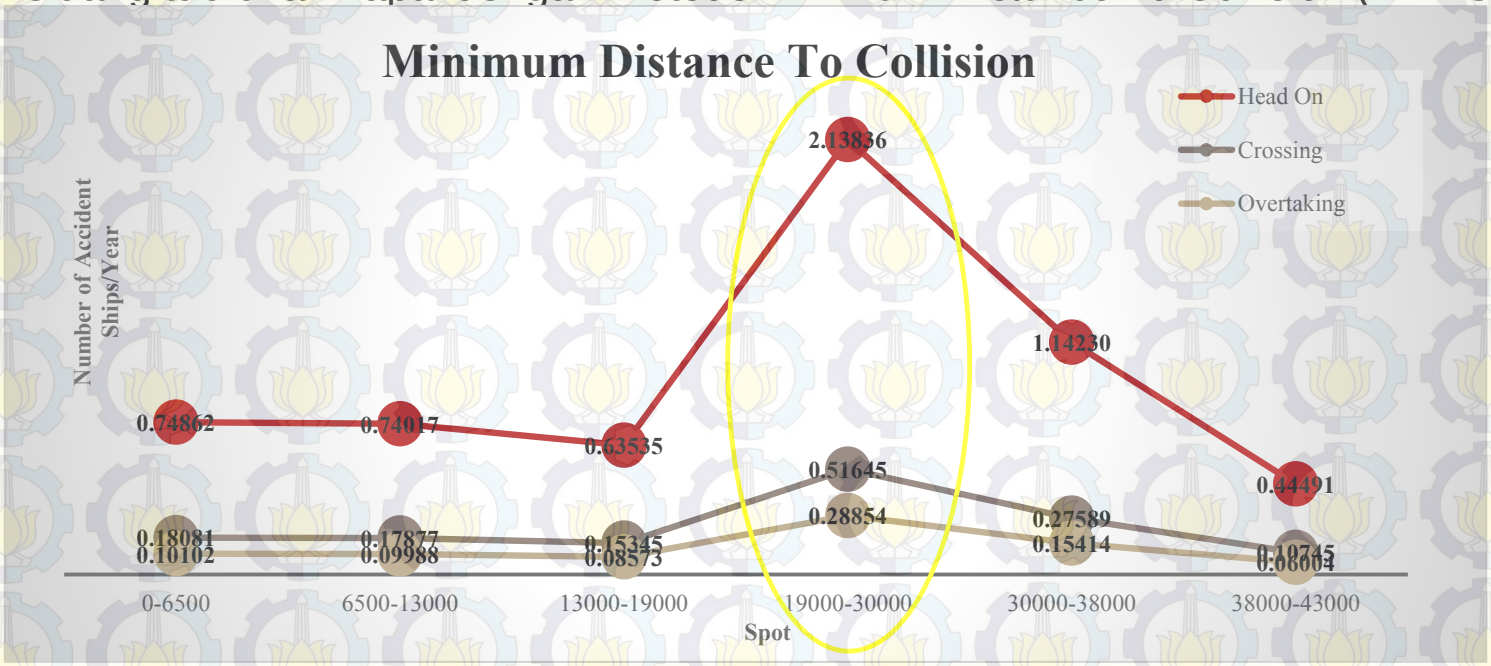
# 6.1. KESIMPULAN

- Dari kedua perhitungan, Tubrukan secara *Head On* merupakan kejadian dengan peluang tubrukan tertinggi bila dibandingkan dengan *crossing* dan *overtaking*.
- Lokasi dengan peluang tubrukan tertinggi pada inner channel spot 19000-30000.
- Peluang tubrukan kapal dengan metode *Traffic Based Models* (TBM) :



# 6.1. KESIMPULAN

- Peluang tubrukan kapal dengan metode *Minimum Distance To Collision* (MDTC) :




- Pc ***Head on*** : *spot* **0-6500=1.37 x 10$^{-3}$**, *spot* **6500-13000=1.40 x 10-3**, *spot* **13000-19000=1.91 x 10-3**, *spot* **19000-30000=1.68 x 10-4**, *spot* **30000-38000=5.89 x 10-4**, *spot* **38000-43000=3.89 x 10-3**.
- Pc ***Crossing*** : *spot* **0-6500=6.27 x 10-2**, *spot* **6500-13000=6.41 x 10-2**, *spot* **13000-19000=8.70 x 10-2**, *spot* **19000-30000=7.68 x 10-3**, *spot* **30000-38000=1.77 x 10-1**, *spot* **38000-43000=3.89 x 10-3**.
- Pc ***Overtaking*** : *spot* **0-6500=2.72 x 10-4**, *spot* **6500-13000=2.78 x 10-4**, *spot* **13000-19000=3.78 x 10-4**, *spot* **19000-30000=3.34 x 10-5**, *spot* **30000-38000=1.17 x 10-4**, *spot* **38000-43000=7.70 x 10-4**.

# 6.2. SARAN

- Menetapkan titik rawan kecelakaan, dimana berdasarkan penelitian, titik yang rawan kecelakaan adalah *inner channel* khususnya *spot* 19000-30000.
- Pentingnya penegakkan batasan maksimum kecepatan kapal pada kapal-kapal yang akan memasuki kawasan APBS, yaitu 10 knots.


Thank You!